Techniques development for the reestablishment of the long-spined sea urchin, *Diadema antillarum*, on two small patch reefs in the upper Florida Keys

First Interim Report, September 17, 2001.

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At this point in the project, about five months after the submission of the proposal and about four months after the first working dive trip to select the reefs sites for the project, the following has been accomplished.

1. The project proposal has been researched, edited, and written.

2. An agreement has been reached with NURC (National Undersea Research Center) to provide scientific assessment of the four project reefs before the translocation of the *Diadema* urchins and six months to a year after this translocation, depending upon initial results.

3. The four project sites, two experimental and two reference patch reefs, were selected about 4 miles eastward offshore of Tavernier FL. The coordinates and approximate size of these reefs areas follows.

Experimental reef #1. N 24.59.177', W 80.26.099', approximately 100 sq. m.
Relatively large coral formations and high relief, largest structures are estimated at up to 2 meters in diameter and about 1.5 meters high.

Experimental reef #2. N 24.59.172', W 80.26.109', approximately 96 sq. m.
Relatively small coral formations and low relief, largest structures are estimated at about 0.5 to 0.75 meters in diameter and less than a meter high.

Reference reef #3. N 24.59.182', W 80.26.117', approximately 72 sq. m.
Relatively small coral formations and low relief, largest structures are estimated at about 0.5 to 0.75 meters in diameter and less than a meter high.

Reference reef #4. N 24.59.108', W 80.26.101', approximately 44 sq. m.
Relatively large coral formations and high relief, largest structures are estimated at up to 2 meters in diameter and about 1.5 meters high.

4. Mapping of the location and approximate size of the coral and rock formations on each of the reef sites was accomplished. Two plastic tape measures were placed over each reef at the beginning of the mapping session to provide a N – S and an E – W axis on the reef. These tapes provided the framework that allowed sequential placement of a 4 sq. m pvc

pipe structure. The size and placement of significant coral and/or rock formations that were present within the 4 sq. m pvc pipe structure was recorded and photographed and the pvc pipe structure was then moved to the next 4 sq. m section of that patch reef. This allowed rapid and accurate mapping of the entire patch reef in 4 sq. m sections. The photograph of each of the 4 sq. m sections provided a "ground truth" record to augment the maps drawn on site. These maps allowed the accurate recording of the placement, numbers and sizes of the *Diadema* urchins that were translocated to the experimental reefs. This work was accomplished during dive trips to the sites on 6/7/01, 7/8/01, 8/17/01, 8/18/01, and 9/3/01.

4. Selection and marking of three, 1 sq. meter areas on each reef that will serve as permanent photography sites was accomplished.

5. NURC accomplished the initial scientific assessment of the project reef sites on 8/31/01.

6. 285 small to large juvenile Diadema urchins were collected on the shallow rubble zone of Pickles reef on 9/4/01 and 9/5/01. These urchins were transported to the experimental reef sites and were released into the coral and rock formations on each of the two experimental reefs. 132 were placed on Experimental Reef #1 on 9/4/01 and 68 were placed on this reef on 9/5/01. 30 were released on Experimental Reef #2 on 9/4/01 and 55 were placed on this reefs on 9/5/01.

The collected urchins were sorted by size, small, 1.5 to 2.5 cm test diameter, medium, 2.5 to 4.5 cm, and large, 4.5 to 6 cm, and the size sorted urchins were moved 10 to a net from the boat to the reef below and placed in specific locations among the coral formations. The size (small, medium, and large), numbers, and placement of the urchins on the reefs were recorded on the map grids of the reef drawn on plastic slates during the underwater placement of the urchins.

7. The two experimental reefs were surveyed on 9/8/01, three and four days after release, and the translocated urchins were located and counted. Most of the urchins remained in the general area where they were released. Of the 200 urchins released on Experimental Reef #1, 160 were found and recorded. Of the 85 urchins released on Experimental Reef #2, 79 were found and recorded.

8. Every phase of the fieldwork of the project was photographically recorded.

Initial Results

The initial phases of the project have been successful. The selected reef sites are representative of typical relatively shallow patch reefs, 20 to 30 feet deep, in the offshore areas of the upper Keys. They are small enough to allow introduction of *Diadema* urchins in densities of 3 to 10 urchins per sq. meter and large enough to demonstrate the biological and ecological changes that are expected from the restoration of pre plague *Diadema* densities. These patch reefs, although in the same general area, are separated by

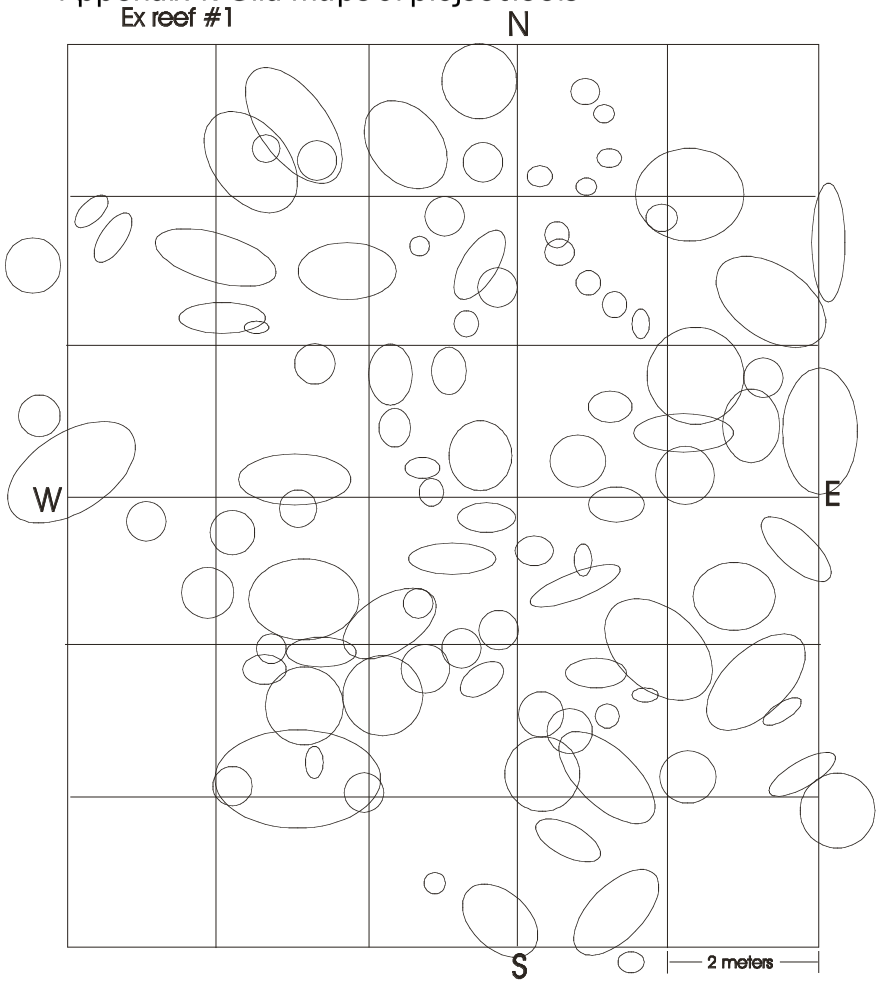
about 30 to 40 feet of grass and sand bottom making it unlikely that the *Diadema* urchins would travel between these reefs.

The urchins initially survived the translocation process very well. After 3 and 4 days, 80% of the urchins released on Experimental Reef # were found alive and well, and 93% of the urchins released on Experimental Reef #2 were found, also alive and well. The greater complexity of the reef structure on Reef #1 and the absence of evidence of mortality, accumulations of spines and pieces of test, indicate that those urchins that we did not find on this count probably also survived but were so well hidden in the reef structures that they were not observed during the count. We also observed normal behavior of the translocated urchins, relative disinterest by potential fish predators, i.e., hogfish, on the reef at the time of placement of the urchins, and evidence of grazing activity of the urchins on the reefs. Thus the indications at this early date are that the translocated urchins will survive and graze the reefs as expected.

Appendix 1. Grid maps of each project reef.
Appendix 2. First reef assessment report by NURC
Appendix 3. Photos from the experimental reefs (by Dr. Stephen Miller)
Appendix 4. Informal dive log of Martin A. Moe, Jr.

Appendix 1. Grid maps of project reefs

Ex reef #1

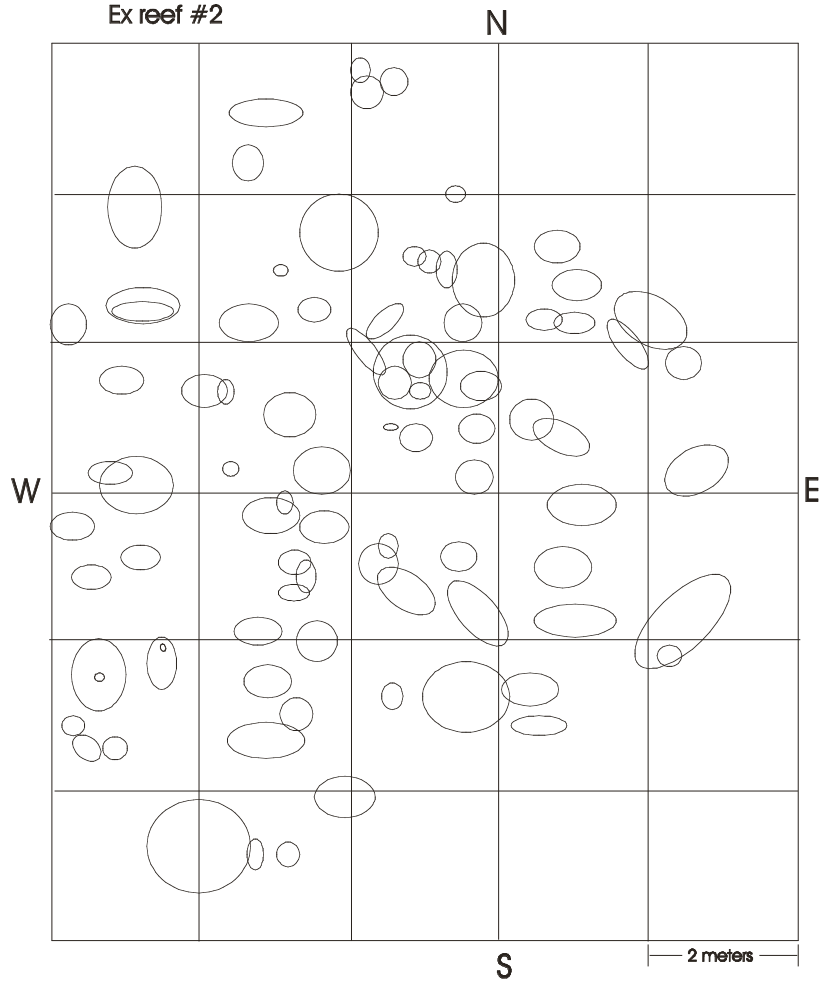


Placement and approximate size of coral formations on Experimental Reef # 1
Diadema urchins released on 9/4 and 9/5, 2001

NW quadrant, 70 NE quadrant, 48

N 24.59.177'
W 80.26.099'

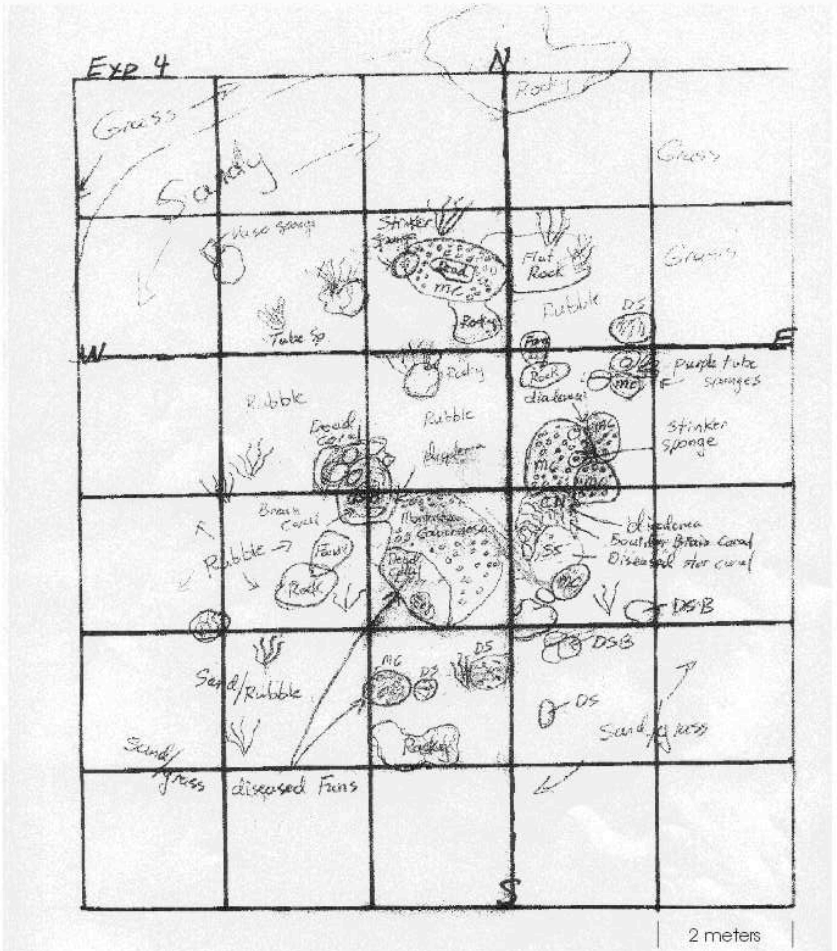
Ex reef #2



Placement and approximate size of coral formations on Experimental Reef # 2
Diadema urchins released on 9/4 and 9/5, 2001

NW quadrant, 20 NE quadrant, 20

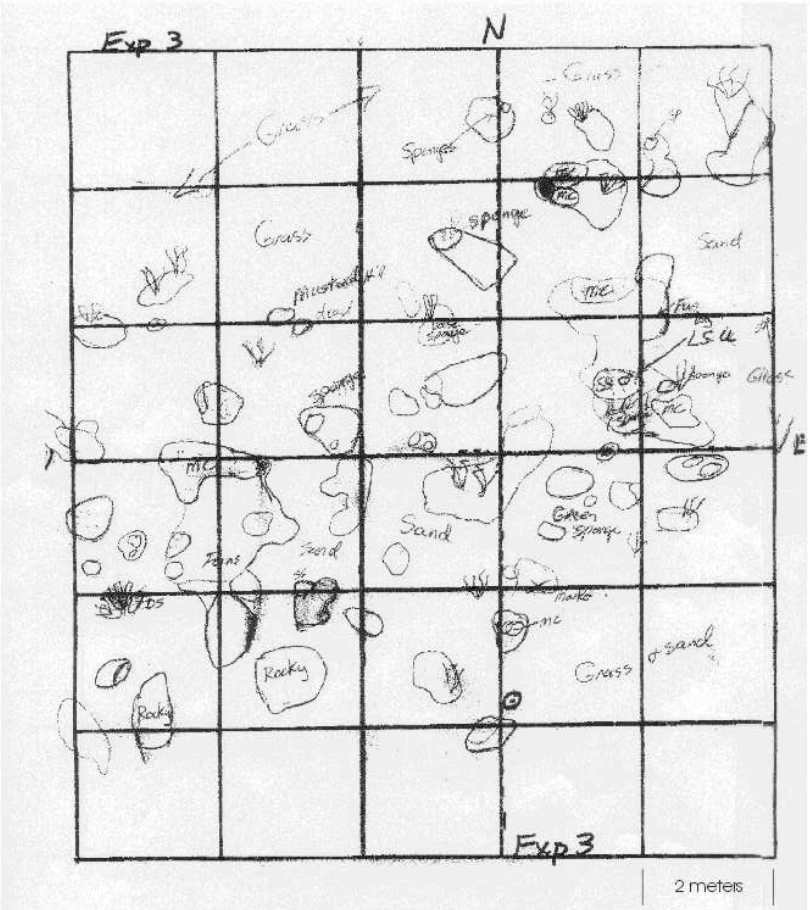
N 24.59.172
W 80.26.108'



Placement and approximate size of coral formations on Reference (control) reef #4

No release of Diadema urchins

N 24.59.108'
W 80.26.101'



Placement and approximate size of coral formations on Reference (control) reef #3

No release of Diadema urchins

N 24.59.182'
W 80.26.117'

Appendix 2. First reef assessment report by NURC

Experimental re-establishment of populations of the long-spined sea urchin, *Diadema antillarum*, on two small patch reefs in the upper Florida Keys

September 2001 Quarterly Report

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Cooperating Institutions and Support:
Florida Keys National Marine Sanctuary, Emerson Associates International, Rosenstiel School of Marine and Atmospheric Science-University of Miami, NOAA's National Marine Fisheries Service, National Undersea Research Center-University of North Carolina at Wilmington, The Nature Conservancy's Florida Keys Program

Habitat Assessment Methods:

Two days of field sampling (August 31-September 1) by benthic ecologists from NURC/UNCW and fisheries scientists from NOAA/NMFS and RSMAS-UM were required to sample the two experimental and two control reefs west of Pickles Reef (Table 1). All four sites are characterized as offshore patch reefs, 7.4-7.5 m in depth, and bounded by moderate to dense seagrass to the west near the seaward edge of Hawk Channel. These sites were complemented by surveys at nine other offshore patch reefs in the upper Keys region, in addition to two mid-channel patch reefs. The benthic sampling was conducted prior to the urchin translocation at the two experimental reefs. Boat support for the habitat assessment was provided by The Nature Conservancy's R/V *Oak Leaf II*, captained by Mr. Alex Creedon. NURC/UNCW-Key Largo provided tank support and all surveys were conducted using SCUBA.

The habitat assessment involved transect surveys of coverage, species richness, and density of reef benthos (Table 2). At each patch reef, coarse maps of the sites were developed. Eight transects, each 10-m in length, were oriented across each patch reef, and used to guide the benthic surveys. The benthic variables measured at the four patch reefs were coverage, species richness, gorgonian density, coral density and size, juvenile coral density, and video for archival purposes. We were also able to assess the following: urchin density and size; density of anemones, corallimorpharians, opisthobranch mollusks, cleaner shrimps, spiny lobster, and arrow crabs; density and predation by the flamingo tongue *Cyphoma gibbosum*; *in situ* measurements of topographic complexity; and estimates of density, length, and biological impacts of remnant

fishing gear and other marine debris. The benthic surveys were complemented by point counts and timed predator surveys of reef fish species composition, density, and length. With the exception of the video transects, all of the variables were collected on pre-formatted plastic slates, facilitating relatively rapid data processing. In addition to digital video, we were also able to take still digital photographs of general site features for archival purposes.

Results and Follow-up:

Summary data are provided on the physical characteristics (Table 4), benthic coverage (Table 5), and density patterns of reef benthos (Table 6) for the two experimental and two control patch reefs surveyed. These data provide the baseline from which to assess the possible responses of the patch reef communities to increased urchin densities. The two experimental sites had greater relief, coral cover, and coral density than the two control reefs. Very low densities of urchins prior to the translocation characterized all four sites.

We expect that the most evident community structure response will be evident in the coverage patterns of algae, especially macroalgae, in the specific microhabitats where urchins were translocated. Follow-up surveys will assess community-wide responses and microhabitat changes in coverage and potentially coral recruitment at the specific translocation sites.

Table 1. SCUBA diving effort by NURC/UNCW and reef fish surveyors.

Diver	Affiliation	No. of dives	Depth range (ft.)	Bottom time
Benthic surveys				
Mark Chiappone	CMSR/UNCW	4	25-29	5 hr 1 min
Dione Swanson	CMSR/UNCW	4	26-27	6 hr 34 min
Helga Dienes	CMSR/UNCW	4	24-27	5 hr 51 min
Reef fish surveys				
Dave McClellan	NOAA/NMFS	2	28	1 hr 54 min
Helena Molina	RSMAS/UM	1	24	1 hr 9 min
Total all divers		15	24-29	20 hr 29 min

Table 2. Habitat variables assessed on two control and two experimental patch reefs in the upper Florida Keys. Transects 10 m in length were used at all sites.

Variable	Method	Factors assessed
Percent cover	Point-intercept along 4 transects	Percent cover, relative abundance
Species richness	0.4 m x 10 m swaths along 8 transects	Species density, total species
Coral density and size	0.4 m x 10 m swaths along 2 transects	Density, size, condition
Juvenile coral density	Twenty 0.68 m x 0.45 m quadrats	Species composition and density
Gorgonian density and height	0.4 m x 10 m swaths along 2 transects	Density, height distribution
Urchin density and size	0.4 m x 10 m swaths along 8 transects	Density, test diameter

Marine ornamentals	0.4 m x 10 m swaths along 8 transects	Density
Spiny lobster density	2 m x 10 m swaths along 8 transects	Density
Fishing gear density	2 m x 10 swaths along 8 transects	Density, length, biological impacts
Topography	0.4 m x 10 m swaths along 4 transects	Maximum relief, substratum slope

Table 3. Mean physical characteristics of experimental and control patch reefs.

Characteristic	Experimental #1	Experimental #2	Control site #1	Control site #2
Minimum depth (m)	7.5	7.4	7.4	8.0
Maximum depth (m)	7.6	7.5	7.5	8.1
Max. vertical relief (cm)	82	41	42	63
Relief distribution (%)				
< 0.2 m	60.0	63.8	77.5	76.3
0.2-0.5 m	35.0	35.0	21.3	17.5
0.5-1.0 m	3.2	1.3	1.3	5.0
1.0-1.5 m	1.3	0.0	0.0	1.3
> 1.5 m	0.0	0.0	0.0	0.0

Table 4. Mean (1 standard error) number of species per 8 m^2) and total species of stony corals, gorgonians, and sponges. Data are based upon surveys of eight 10-m x 0.4 m transects at each site.

Taxa	Experimental #1	Experimental #2	Control site #1	Control site #2
Stony corals				
Mean species/8 m^2	11.75 (0.25)	10.00 (1.08)	11.25 (1.11)	9.75 (0.75)
Total species	20	15	17	15
Gorgonians				
Mean species/8 m^2	4.75 (0.48)	11.00 (1.00)	8.50 (0.96)	6.00 (0.41)
Total species	8	18	15	10
Sponges				
Mean species/8 m^2	21.75 (0.63)	26.25 (1.80)	24.25 (1.89)	19.50 (0.50)
Total species	35	35	35	28

Table 5. Mean (1 standard error) percent coverage of reef benthos and abiotic components. Data are based upon surveys of 100 points along each of four 10-m transects per site.

Bottom type	Experimental #1 (reef #1)	Experimental #2 (reef #2)	Control # 1 (reef #3)	Control #2 (reef #4)
Agaricia agaricites	0.25 (0.25)	0.25 (0.25)	0.50 (0.29)	0.25 (0.25)
Colpophyllia natans	1.00 (1.00)			1.00 (1.00)
Dichocoenia stokesi		0.25 (0.25)	0.50 (0.29)	
Millepora alcicornis		0.25 (0.25)	0.50 (0.29)	0.25 (0.25)

Montastraea annularis	1.00 (1.00)			
M. faveolata		0.25 (0.25)	1.00 (1.00)	
M. cavernosa	6.50 (4.57)	1.00 (0.71)		6.75 (3.90)
Porites astreoides	1.00 (0.41)	0.25 (0.25)	1.50 (0.96)	1.50 (0.50)
P. porites furcata	0.50 (0.29)		0.50 (0.29)	0.25 (0.25)
P. porites porites		0.25 (0.25)		
Siderastrea radians	0.75 (0.25)			
S. siderea	3.00 (0.91)	3.00 (2.04)	0.25 (0.25)	2.00 (0.71)
Solenastrea bournoni			1.25 (1.25)	
Stephanocoenia michelini			0.25 (0.25)	
Total coral cover	14.00 (4.56)	5.50 (2.10)	6.25 (2.21)	12.00 (4.45)
Branching gorgonians	0.25 (0.25)	0.50 (0.29)		0.25 (0.25)
Encrusting gorgonians				
Total gorgonian cover	0.25 (0.25)	0.50 (0.29)		0.25 (0.25)
Anemones	0.25 (0.25)			
Zoanthids	0.25 (0.25)	0.50 (0.29)		0.50 (0.29)
Sponges	5.75 (1.18)	8.25 (2.39)	6.75 (1.31)	3.75 (1.49)
Fine algal turf	30.25 (1.89)	26.00 (2.12)	21.50 (4.77)	25.00 (4.92)
Thick algal turf	0.50 (0.29)	0.50 (0.50)		0.25 (0.25)
Crustose coralline algae	6.25 (1.70)	8.75 (1.55)	6.25 (1.65)	9.25 (2.59)
Green foliose algae	0.75 (0.48)	1.00 (0.71)	0.25 (0.25)	1.25 (0.75)
Green calcareous algae				
Halimeda spp.	4.00 (0.41)	2.25 (0.95)	2.00 (0.71)	0.50 (0.50)
Penicillus spp.			0.50 (0.29)	
Udotea spp.	0.25 (0.25)	0.25 (0.25)	0.25 (0.25)	0.25 (0.25)
Brown foliose algae				
Dictyota spp.	9.25 (2.66)	5.75 (2.17)	4.00 (0.91)	1.50 (0.87)
Lobophora variegata	1.50 (0.87)	2.75 (0.75)	0.25 (0.25)	1.50 (0.96)
Sargassum spp.	0.25 (0.25)	0.50 (0.50)	1.75 (1.18)	
Red foliose algae	0.50 (0.29)	0.25 (0.25)		
Red calcareous branching	0.50 (0.29)	0.25 (0.25)		
Cyanobacteria/diatoms	1.75 (0.48)	2.75 (1.55)	15.25 (4.66)	5.75 (1.11)
Total algal cover	56.75 (1.31)	51.75 (6.12)	52.00 (5.99)	45.25 (5.19)
Sand	12.75 (2.63)	14.00 (2.80)	21.00 (9.16)	21.50 (5.52)
Sand on hard-bottom	8.75 (3.40)	19.50 (4.99)	14.00 (4.34)	16.25 (5.63)
Silt on hard-bottom	1.50 (0.87)			0.50 (0.29)

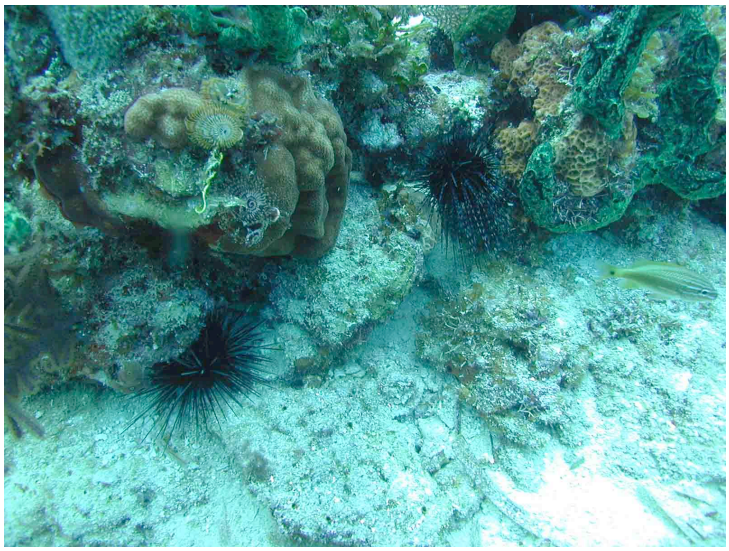
Table 6. Mean (1 standard error) densities (no. per m^2) of gorgonians, stony corals (> 4 cm diameter), juvenile corals (< 4 cm diameter), and urchins.

Species	Experimental #1	Experimental #2	Control site #1	Control site #2
Gorgonians				
Briareum asbestinum			0.13 (0.13)	
Erythropodium caribaeorum		0.25 (0.00)		
Eunicea calyculata		0.25 (0.00)	0.13 (0.13)	
E. fusca		0.13 (0.13)	0.13 (0.13)	
E. laciniata			0.13 (0.13)	
E. mammosa		1.00 (0.25)	0.75 (0.25)	
E. succinea		0.13 (0.13)		
E. tourneforti		0.25 (0.00)		
Gorgonia ventalina	1.13 (0.63)	2.25 (0.50)	1.00 (0.50)	1.13 (0.38)
Muricea muricata		0.13 (0.13)	0.25 (0.25)	
Muriceopsis flavida		0.25 (0.25)	0.13 (0.13)	0.13 (0.13)
Plexaura flexuosa		0.13 (0.13)	0.25 (0.25)	
P. homomalla	0.13 (0.13)			
Plexaurella dichotoma		0.38 (0.38)	0.13 (0.13)	
Pseudoplexaura crucis	0.13 (0.13)			0.13 (0.13)
P. flagellosa		0.13 (0.13)		
Pseudopterogorgia acerosa	0.75 (0.50)	0.25 (0.25)	0.50 (0.00)	0.38 (0.13)
P. americana	1.75 (0.00)	3.00 (0.00)	3.63 (0.38)	2.50 (0.00)
Total gorgonian density	3.88 (1.13)	8.50 (0.00)	7.13 (1.38)	4.25 (0.25)
Stony corals (> 4 cm)				
Agaricia agaricites		1.19 (0.69)	0.50 (0.50)	0.63 (0.38)
A. fragilis				0.13 (0.13)
A. humilis	0.23 (0.23)	0.31 (0.31)	0.50 (0.50)	
Colpophyllia natans				0.13 (0.13)
Dichocoenia stokesi		0.50 (0.50)		
Diploria clivosa		0.31 (0.31)		
Madracis decactis	0.31 (0.31)			
Millepora alcicornis	1.08 (0.17)	3.00 (0.50)	2.50 (0.50)	1.00 (0.25)
Montastraea cavernosa	3.01 (0.74)	0.75 (0.75)		1.00 (0.25)
M. faveolata			0.25 (0.25)	
Porites astreoides	1.85 (0.03)	4.19 (0.19)	1.38 (0.38)	1.00 (0.75)
P. porites furcata			0.63 (0.13)	0.50 (0.00)
P. porites porites	0.31 (0.31)	2.38 (1.13)	0.13 (0.13)	0.13 (0.13)
Siderastrea radians	0.23 (0.23)	0.25 (0.25)		
S. siderea	1.90 (1.28)	1.75 (0.75)		0.50 (0.25)
Solenastrea bournoni	0.23 (0.23)		0.63 (0.13)	
Stephanocoenia michelini	0.23 (0.23)		0.25 (0.25)	
Total coral density	9.38 (0.63)	14.63 (0.88)	7.00 (0.50)	5.00 (0.75)

Juvenile corals (< 4 cm)				
Agaricia agaricites	0.32 (0.32)			1.60 (0.32)
A. humilis				0.32 (0.32)
Dichocoenia stokesi			0.16 (0.16)	
Montastraea cavernosa		0.32 (0.32)	0.32 (0.32)	
Porites astreoides	1.28 (0.32)	1.76 (0.48)	2.08 (1.76)	2.72 (0.48)
P. branneri				0.16 (0.16)
P. porites divaricata			0.16 (0.16)	
P. porites furcata	0.80 (0.48)	0.32 (0.00)		
Siderastrea radians	3.85 (0.96)	3.04 (0.80)	2.40 (1.44)	1.60 (0.32)
S. siderea	0.16 (0.16)	0.32 (0.32)	0.48 (0.16)	0.48 (0.16)
Solenastrea bournoni	0.16 (0.16)		0.32 (0.32)	
Stephanocoenia michelini				0.32 (0.32)
Total juvenile density	6.57 (0.80)	5.77 (0.64)	5.93 (0.16)	7.21 (0.80)
Urchins				
Diadema antillarum				0.16 (0.08)
Echinometra viridis	0.03 (0.03)	0.03 (0.03)		
Eucidaris tribuloides	0.03 (0.03)	0.03 (0.03)	0.03 (0.03)	0.03 (0.03)
Total urchin density	0.06 (0.06)	0.06 (0.06)	0.03 (0.03)	0.19 (0.11)

Appendix 3. Photos from the experimental reefs (by Dr. Stephen Miller)

Ken Nedimyer searches the reef for *Diadema* urchins



Translocated Diadema urchins find a new home on the reef

Appendix 4. Informal dive log of Martin A. Moe, Jr.

June 7, 2001

First dive trip for the Diadema Project. Ken and I left from Harry Harris Park at about 11:30 AM and traveled to the site where Ken had identified some potential small patch reef sites near Conk Key. Winds were out of the southeast at about 15 mph and the water was fairly rough, 3 to 4 foot seas. I made two dives and Ken made three. On the first dive, we first explored the general area and found about 5 or 6 small reef areas that had potential for the study. We then identified two small patch reefs, one with some large coral heads 3 to 5 feet high and perhaps 4 feet in diameter one with lower rock and coral outcroppings that seemed ideal for the experimental reefs. One adjacent low patch reef seemed good for one of the control reefs. Ken knows of a third patch reef in the vicinity that we did not visit that also has some higher coral growth and would probably be a good control reef to compare with the more rugged experimental reef. Ken will follow up on this reef later and we will check this area out on a later visit.

On the second dive, we made some rough sketches of these areas and obtained measurements of these reefs with a plastic tape measure. Ken has these sketches and measurements. We also marked the two experimental reefs with a submerged line with two styrofoam trap buoys and the one control reef with a single submerged buoy. Ken also took some video of these areas. We observed several (Moe 3, Ken 4) Diadema urchins in this general area. I did not distinguish which reefs they were occupying on this visit and they were not necessarily on the patches we selected as the project reefs. They were located under coral heads and rocks that had relatively large open spaces under them. I did not make an attempt to identify and record the reef life that I observed on this visit. My recollections, however, include observation of a number of red groupers, about 5 or 6, scattered about the area, one almost 3 feet in length, that were not particularly spooked by our presence. There were many species and large numbers of smaller fish. I could list perhaps 20 or more species from memory including a very large green moray eel. I observed no lobsters during either of my dives. Extensive algal growth was present on most reef structures. I recall strong growths of the brown alga Padina, attached Sargassum and Dictyota.

Ken made a short third dive to recover samples of what appeared to be black band disease on a moderate sized coral head.

We then headed back to dock and retuned to Ken's house at about 4 PM.

July 8, 2001

A beautiful Sunday afternoon. Ken and I made the second dive trip to the Diadema site. We left the dock at about 2:30 PM and returned at about 5:00 PM. The weather was beautiful and the water was clear and a calm, a perfect day. Had time for only one dive of

about 1.5 hours. We explored and did the initial mapping of the two experimental sites. We set up a north – south line on each reef with pvc stakes placed at each end of the reef. Experimental reef # 1 is the relatively high, rugged coral reef (the coral heads are numerous and are generally about 1 to 1.5 meters high and a meter in diameter) and experimental reef # 2 is the low hard bottom reef with only a few large coral heads but many small coral formations only .25 to .5 meters high. Both # 1 and # 2 experimental reefs were about the same size and fit into a 12 by 10 meter square.

There were many fish on both reefs, but the more rugged reef #1 had a larger and more diverse fish population than reef # 2. No lobster were seen on either reef and one Diadema urchin was observed on reef #2. Ken had previously observed one Diadema on the same reef and if this was the same one, it had moved about 3 meters from its previous location.

We made rough maps of the locations of various coral heads based on their distance from the north – south axis that we established through the reef .

August 17, 2001

The third dive trip to the Diadema project site was on Sunday, August 12, 2001. We left at about 2:30 PM and returned at about 5:30 PM. We made two dives, both on experimental reef #1.. The two pvc pipe markers we had left at the ends of the N and S lines on the reef had become dislodged and no longer marked these lines. We knew where they had been, however, and we could lay out two measuring tapes over the entire reef, one N to S and one E to W with the crossing at about the center of the reef We then laid out marked ropes at 2 meter intervals creating a grid that formed squares two meters on a side, four square meters in each section. We then mapped the major features within each grid section and I then took photographs of each section. Ken also placed stainless steel spikes at the intersections of the grids and marked them with fluorescent cable ties. This way we have a record (and map) of the extent and the topography of the reef and we can record exactly how many, and where and when the translocated Diadema are placed on the reef.

My photographs were adequate, but they can be much improved by taking the photos at the same distance above the reef each time (determined with a weighted line of specific length) and with better demarcation of the section photographed. Ken has made a four square meter pvc pipe grid section that can be used to sequentially mark off the grid sections on each reef. We will only have to lay out the two directional tapes and then use the pvc pipe section to mark off each section, map and photograph it, and them move the pipe square to the next section. This will make a very noticeable border on each section for the photographs and the process will be very much quicker.

We did not do any biological assessment of the reefs, but I noticed that there were no urchins or lobsters on the reef.

August 18, 2001

Ken and I made another trip to the Diadema site. We left at about 11:00 AM and returned at about 5:00 PM. The purpose of the trip was to map and photograph the remaining three project reefs. The exact location of each of these reefs is recorded with Ken's GPS and we marked each reef with a submerged buoy when we first selected the project reefs. On the last trip we mapped and photographed Experimental reef # 1, and with what we learned on that trip, we were able to improve our techniques and accomplish these tasks much more quickly and efficiently on the remaining reefs. Instead of stringing marked ropes at two meter intervals over the patch reefs to demark the 4 square meter sections (as we did on the last trip), we used a 4 square meter (two meters on a side) pvc pipe grid to outline each section of the reef and sequentially mapped and photographed each section. We first laid down two tapes (marked in feet and meters) on a north/south and an east/ west axis over the patch reefs. This separated the reef into for quadrants, NE, NW, SE, and SW. Beginning at the center, we then laid down the pvc pipe grid, mapped the coral formations and bottom type that occurred in that section and also took a photograph of that section outlined by the pvc pipe grid. This makes it possible to lay out the photographs according to the sections, thus creating a large mosaic picture of the structure of the patch reef to augment and detail the map on the plastic slate. With this map we can record exactly where and how many urchins are placed on each reef, and also record at each subsequent visit, where the urchins move and where they best survive. We can, if necessary, redeploy the pvc pipe grid in the future to precisely define the location of a particular formation, but this should not be necessary as the map and photographs will provide a precise location. We have not yet selected the three, one square meter sites on each reef that will be the permanent photo-quadrats for photography of reef conditions over the term of the project, but this will be easy to do on the next visit.

Ken and I will go over the data and provide the following basic information, along with the working maps of each reef, very soon.

Reef #1, Experimental restoration
Reef #2, Experimental restoration
Reef #3, Reference
Reef #4, Reference

Location:
N/S length:
E/W length:
Number of sections in each quadrant: NE, NW, SE, SW,
General description:

After we get the final maps of the reefs down on the working slates, we should be able to begin translocation of the small Diadema as soon as conditions and availability (and permits) are forthcoming. NURC should probably plan to do the pre translocation survey in the near future. We did observe a few, 3 to 5, Diadema urchins on the reference reefs but none on the experimental reefs and this will give us an estimation of the extent of

natural populations of Diadema on these reefs at the start of the study. (Ken has all data on the dives at this point so I don't have that exact information at this time.)

Although we are a little behind schedule at this point, things are going well with the initial phase of the project and if the urchins cooperate and we get good settlement in the next month or two, we will be off and running.

September 3, 2001

Ken and I made the last mapping and photography trip to the Diadema site on Labor Day. The wind was out of the east at bout 10 mph and there were 2 to 3 foot swells. We revisited experimental reef # 1 to retake the "ground truth" photos of each 4 sq. m section of this reef and to complete the mapping process (using the 4 sq. m pvc pipe section instead of the rope grid) on the grid on the plastic slate that we will use to record the number and placement of the translocated urchins. I took the first photos of this reef with the 28 mm lens on the Nikonos and those were barely adequate. The 15 mm lens does a much better job since the distance between the camera and the subject is much shorter. All went well and I got the required photos and the Ken made the map entries on the grid. We then established the 1 m sections that we will use as permanent photography sites to record changes that may occur on the reefs as a result of the Diadema placement. I then shot two roll of slide film on Experimental reefs # and # 2 of various areas and various subjects which well give us an overall sense of reef condition on these reefs before translocation of the urchins.

We observed three Diadema urchins on Experimental reef #1, two adults and one juvenile, the juvenile had a test diameter of about 1.5 cm (my estimate). The adults were well hidden deep under one of the major bolder coral formations and the juvenile was tucked deeply under a small rock ledge.

September 4, 2001

To Brian, Billy and Joanne,

This is just a quick note at the end of a hard and exciting day to let you know, unofficially, how it all went from my perspective. Ken and I and my friend Mike (a very old friend of mine who happens to be visiting us this week and didn't mind being put to work) went out at about 1:30 PM to do the first urchin translocation. We went to Pickles because that is where Ken had seen considerable numbers of small Diadema. Ken and I worked the rubble zone for about two hours and collected about 150 Diadema (Ken has all the data at this point so I'm working just on recollection) that ranged in size from small, about the size of a large marble, medium, golf ball size, and large baseball up to softball size. We placed them in Ken's collection container on the boat and then went over to the experimental sites.

We used the grid maps to decide where we wanted to place them and how many would go in each selected area. Mike put 10 each into separate nets and we ferried them down to

the reefs. We placed them into and at the edge of the selected coral and rock structures and then tried to push them in and under cover. This was not necessary. Did you ever see an urchin scurry? These guys did, big time. By the time the net was empty and I went back to try to encourage them to get to cover, they were climbing into the reef and finding niches and waving their spines like they owned the place, which, come to think of it, they do. They moved into the reef so quickly you wouldn't believe it. After all the urchins were distributed, about 5:30 PM, Ken and I spent another 45 minutes or so taking pictures and watching the urchins and looking for signs of predation or disorientation and found nothing that would even begin to indicate that any potential predator was even slightly interested. (Incidently, we have photographic documentation of all phases of the operation.) I followed a hogfish all over the reef and he (she) did not show any interest in even the smallest of the urchins. As time went by the urchins spread into the niches in the reef and under the coral heads until they almost disappeared and you had to crawl under the structures to see them. I can't believe that there is any possibility that these urchins will not survive this translocation.

But we will see. Ken, Mike and I are going out again tomorrow at 10 AM to do it again. We would like to get at least 300 on the two experimental reefs to start off the project. I think we can hit that number if we are as successful at collection as we were today. We will make a quick stop at the experimental reefs before the collection to check and make sure that the urchins placed today have survived the translocation so far. If not we will reassess the situation, but if, as I fully expect, the urchins have survived, we will proceed with the additional translocation. At that point, after about 300 are translocated, we will wait a week or two and see how they survive and how they distribute themselves, and then perhaps try to increase the numbers to preplague densities.

I am greatly encouraged by the behavior of the urchins and the apparent acceptance of them by the denizens of the reefs at this early point. I think it is going to work. If it does it will demonstrate (I think, hope) that 1. the condition of the reefs can be significantly improved by replacing the Diadema population. 2. that the increased propinquity of the urchins will increase reproductive success and the increased larval production will increase settlement of post larvae on broad areas of the reef. and 3. it will encourage similar projects in other areas of the Keys. And perhaps 4. it will stimulate more work on hatchery production of juveniles, which, I think, can with experimentation be released as competent juveniles.

September 5, 2001

Ken, Mike and I went out for the second day of urchin translocation. We left about 10:30 AM and returned about 5:PM. We first visited the experimental site to determine how the first 150 urchins survived their first 24 hours in their new location. We (I) saw no sure signs of predation. There were a few spines scattered around in few areas but I think that most of these were from spine loss at time of removal of the urchins from the net upon placement on the reef. Ken found a few spines from a small urchin that he thought might have been a sign of predation by a burrfish or porcupinefish, Diodon histrix. This may have been the case, but if such predation did occur it was very minor. Ken was able to

count the same number of urchins in specific areas that we had liberated in those areas the day before. I did not count urchins but I looked intensively at all the coral formations and found numerous live and active urchins in all the areas where they were placed. The smaller urchins were extremely well hidden deep in the reef areas and for the smaller urchins, the only sign of their presence was a little tuft of waving spines protruding from a small crevice or hole deep under or between the reef formations. The larger urchins were occupying larger crevices and niches in the reef and the reef looked very much like it did back in the 70's.

We decided that survival over the first night had been very close to 100% and that a second collection and translocation was the order of the day. We went back to Pickles, Ken has the coordinates of the areas where we collected and the numbers of urchins taken from these areas. All came from the broad shallow rubble zone on Pickles reef. We collected again about 150 urchins (Ken has the exact data.) and transported them to the experimental sites. (This sounds easy, collecting sea urchins in 6 to 10 feet of water, after all sea urchins can't move very fast, but when you add in the surge factor and the fact that the spines on these urchins penetrate the flesh very easily, it is not an easy task.) At the experimental reefs we repeated the procedure of the day before. Ken used the grid maps on the plastic slates to guide the distribution of the urchins to the various areas and I brought them down from the boat in groups of 10 per net, two nets per trip. We then placed them in designated areas on Experimental reefs 1 and 2, and made sure that they went in the reef structures, which was no problem since they somehow could sense exactly where the corals and rocks were and scurried (OK so this is not a scientific term, but that's exactly what they did, scurry) over to and into the reef structures. They went directly toward the reef structure, there was no wandering about and then blundering into a rock structure. They went quickly and directly into the largest structures in their immediate vicinity. We then took numerous photographs and video and observed the urchins settle into their typical behavior patterns and watched for any signs of mortality or predation. I saw no mortality in the new urchins or in the urchins released yesterday, in fact, within a very short time I could not determine which were the new urchins and which were had already been there for a day. We also noticed one area on the smooth inner surface of where there were apparently fresh marks that indicated grazing activity by the translocated urchins.

We now have about 300 urchins on the two experimental reefs, most on the reef with the most extensive coral structure, reef # 1. Ken will visit these reefs again, probably on Saturday, Sept. 8, to make another visual check for mortality and to make a quick estimate of survival. If all goes well with this population for the next week or two, if mortality in the translocated urchins is low, and if urchins in the rubble zones are still available we plan to augment the populations that are already on the experimental reefs. I have yet to do the calculations on numbers per sq meter to determine what we now have and what we need to approach pre plague densities of 5 to 15 per sq meter. When we do this we will have better idea on where we are where and where we need to be if possible. Observing how the 300 now in place distribute themselves in their daytime niches will be helpful in determining how many to ultimately place on these reefs.

At this point things seem to be going very well. I will get with Ken in the near future to go over the data and I will then prepare the first project report, hopefully within a week or two.

September 8, 2001

Ken, myself, and Stephen Miller (NURC) visited the reefs selected for restoration work (experimental reefs) for a first count of the translocated *Diadema* urchins and an assessment of the survival, condition, and grazing activity of the urchins. We left the dock at about 8:45 AM and returned at about 12:00 PM. Dr. Alina Szmant, a scientist from the University of North Carolina currently engaged in extensive Diadema research on Keys reefs joined us at the site in midmorning for look at the translocated urchins. We were all impressed and heartened by the obvious near 100 percent survival and excellent condition of the *Diadema* urchins on both experimental reefs.

Ken made the first official count of the urchins that he could find on both reefs and his numbers were as follows.

Experimental reef # 1. Total of 200 released on 9/4 and 9/5. Total counted on 9/8, 160.

Experimental reef # 2. Total of 85 released on 9/4 and 9/5. Total counted on 9/8, 79.

Reef # 1 contains several complex areas of relatively high and extensive coral formations and it is difficult to find small urchins in these complex formations. We are confident, however, based on the lack of aggregations of loose spines and test particles and the obvious acclimation of the small urchins that we did see, that mortality of the urchins not accounted for is very minor, if it occurred at all. We think that most of these 40 urchins are still present on the reefs, but were hidden deep in the coral at the time of the count. Reef #2 contains mostly small and low coral formations and the urchins are more visible in this environment and the count, 85 released, 79 observed, is more indicative of the extent of survival than the count on Reef #1. However, even if all the uncounted urchins did not survive, the percentage of survival is still 84%.

I did some rough calculations on the density of urchins that have been released on the experimental reefs to this point. The calculations are rough estimates, but are probably about as accurate as it will be possible to obtain. For this estimate, I counted the 4 sq. m sections on both maps that seemed to contain significant coral and rock formations. Sections that were mostly grass or smooth hard bottom were not counted. We can be much more precise with this if we use the photographs of each section to aid in this determination.

The developed reef area on Reef #1 is composed of roughly 26, 4 sq. m sections, a total area of about 104 sq. m. With a total of 200 urchins released on this reef so far, that is a density of about 2 urchins per sq. meter.

The developed reef area on Reef #2 is composed of roughly 22, 4 sq. m sections, a total area of about 88 sq. m. With a total of 85 urchins released on this reef so far, that is a density of about 1 urchin per sq. m.

We took numerous photographs of the reef, the urchins, and Ken in the process of his count. Ken used the slates of the grid map to record the locations of the counted urchins and we will be able to compare the 9/8 counts with the location records of where the urchins were released on 9/4 and 9/5. The release and subsequent count records include the size range of the urchins as well as the location on the reefs.

During this dive I observed the two large urchins and the small juvenile that I had observed on Reef # 1 prior to the release of the urchins and they were still in the same locations. There was also a large lobster on Reef #1 that was not present in previous trips. The fish populations appeared not to have changed from prior trips but no effort was made to record the species or to quantify the fish fauna.

September 21, 2001

Ken, Brian Keller, Sanctuary Science Coordinator, Joanne Delaney, Sanctuary Research Interpreter, and I made a trip to collect and translocate additional urchins to the experimental reefs of the Diadema project. We left the dock at about 10:00 AM and returned at about 2:00 PM. We first went to the shallow rubble zone of Conch Key and spent about two hours collecting urchins. We collected about 100 urchins, Ken has the exact number collected, the size ranges, and the placement of the urchins on Experimental reef # 2 (all the urchins were placed on this reef). Most of the urchins were in the medium to large category, with, as I recall, about 25 in the small category. Note that these size ranges, small, medium and large, pertain to juvenile urchins, not to the full range of size that a population of mature Diadema urchins would include. The largest of these juveniles, had a test size that in my estimation was no larger than a baseball, and most were considerably smaller than this. The urchins on this site, Conch Key, as compared to the collections on Pickles Reef, appeared to range a bit larger in size.

After collection of the urchins, we moved over to the project site and anchored near Experimental Reef # 2. The two experimental reefs are so close, separated by only about 40 feet of grass, that both reefs are easily worked from any nearby point of anchor. We discussed placement of the urchins before the translocation dive, and decided to place them all on Experimental reef # 2. The density of urchins on Experimental reef # 1 at this point was about 2 per sq. m and that of Exp. Reef # 2 was only 1 per sq. m. Placing all 100 urchins on Reef #2 would bring both Reefs to a density of about 2 per sq. m.

Ken had visited the site last Wednesday, Sept. 19, and made a complete count so we did not take the time to make another count on this trip. I don't have the exact figures on Ken's last count yet, but as I recall from the numbers he told me, his count was a little higher on the Sept. 19 count than the count of Sept. 8. Which indicates that the urchins are acclimating well to the new conditions on the patch reef and mortality among the translocated urchins is very low if any has occurred at all. Joanne stayed in the boat while Ken, Brian and I made the translocation dive. Ken directed the placement of the urchins based on the maps and previous placements of urchins. Joanne sorted the urchins by size

and placed them in the nets. I ferried the nets of urchins down to the reefs and Ken and I placed them in the appropriate reef structures, and as before, they immediately "scurried" into the nearby reef structures. Brian watched us move the urchins and examined the reefs and took notes on his observations during the dive.

I took photographs and examined the reefs closely at the end of the urchin translocation. I saw no sign of urchin mortality and a lot of what I think is evidence of urchin activity on the reefs. The large urchins that we translocated were readily observed all over the both reefs and the small ones were hidden in the reef structures and required careful observation and scrutiny under and within the reef structure to find them. Eppie, the 3 foot red grouper with the scratches on her head and left operculum, followed us around as usual and observed us carefully as we worked Reef #1. She has been on that reef in the same area since the first visit.

Ken is also helping Alina Szmant with her study of Diadema urchins, particularly the introduction and monitoring of small tank reared Diadema in natural reef areas. There has been, as I understand it, high mortality in the small tank reared urchins placed in natural areas and Ken and Alina have set up a small experiment in an area separate from, but near by our project sites. Ken has established four small areas on a nearby low profile reef and placed a small number of tank reared urchins on two of these areas and about the same number of wild urchins (around 5 to 10 urchins on each site). We visited this area at the end of the dive to count the tank reared and the wild urchins. Ken has the numbers on this count. It appeared to me (empirical observation) that the wild urchins were more numerous, apparently experiencing little mortality; while the tank reared urchins were considerably fewer in number. The tank reared urchins were of different appearance, shorter, fewer spines and darker in color, than the wild urchins. The tank reared urchins also seemed less integrated into the reef structure and were more easily observed than the wild urchins. Although some were in niches in the reef, several were found in rather open areas, sand pockets, of the reef structures.

Brain and Joanne both seemed impressed with the detail, documentation, and results of the project at this point. At the end of the trip, Brian, his wife, Fiona, Ken and I had a late lunch and discussed many things pertaining to the project. In particular, I wanted to set a reasonable and doable density figure that we should aim for on the Experimental reefs. Complexity of reef structure is a consideration since a rugged complex structure should support more urchins a low hard bottom. It is also a given that over time the urchins themselves will move to areas that offer the best shelter and sources of food. We decided that a level of about 4 Diadema per sq. m would provide a close enough density to approximate pre plague densities on these reefs. This is a "guessestimate", of course, and there are many, many questions that have no answer at this point in this regard, but we feel that this figure, 4 per sq m, about double the present density on the Experimental reefs, will give us a strong population that will produce significant results within the time frame of the project. We should be able to accomplish this with two or three more translocations within the next few weeks.